(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 506 476 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent: 05.06.1996 Bulletin 1996/23

(51) Int Cl 6 H01P 1/203

(21) Application number 92302748.6

(22) Date of filing 27.03.1992

(54) **Dielectric filter having coupling electrodes for connecting resonator electrodes, and method of adjusting frequency characteristic of the filter**

Dielektrische Filter mit Koppelelektroden um Resonatoren oder Elektroden zu Verbinden, und Verfahren zur Einstellung der Frequenzcharakteristik des Filters

Filtre diélectrique avec des électrodes de couplage pour relier des résonateurs ou des électrodes, et méthode pour ajuster la caractéristique de fréquence du filtre

(84) Designated Contracting States: **DE FR GB IT**

(30) Priority: **29.03.1991 JP 93092/91**

(43) Date of publication of application: **30.09.1992 Bulletin 1992/40**

(73) Proprietor: **NGK INSULATORS, LTD.**
Nagoya-shi, Aichi-ken 467 (JP)

(72) Inventors:
- **Hirai, Takami**
  Nishikamo-gun, Aichi-ken (JP)
- **Yano, Shinsuke**
  Nagoya-shi, Aichi-ken (JP)

(74) Representative: **Paget, Hugh Charles Edward et al**
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

(56) References cited:

EP-A- 0 346 672	EP-A- 0 414 619
US-A- 3 512 110	US-A- 4 418 324
US-A- 4 673 902	US-A- 4 963 843

- **PATENT ABSTRACTS OF JAPAN vol. 12, no. 3 (E-570)(2850) 7 January 1988 & JP-A-62 164 301**
- **PATENT ABSTRACTS OF JAPAN vol. 12, no. 367 (E-664)(3214) 30 September 1988 & JP-A-63 119 302**

EP 0 506 476 B1

Printed by Jouve 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates in general to a dielectric filter for the microwave spectrum of frequency and a method of adjusting the frequency characteristic of the dielectric filter. More particularly, the present invention is concerned with a small-sized dielectric filter constructed for excellent filtering properties, and a method by which the frequency characteristic of such dielectric filter can be easily adjusted.

Discussion of the Prior Art

In a microwave telecommunication system of modern vintage such as a portable or automobile telephone system, various filters using dielectric ceramics are used for minimizing the transmission loss. A known dielectric filter has a plurality of coaxial type resonators connected to each other. Each resonator is a dielectric block which has a central through-hole whose cylindrical surface is metallized to provide a central conductor serving as a resonating element. However, the central through-holes of the resonators have been a limiting factor to an effort to reduce the thickness and size of this type of dielectric filter. Further, this dielectric filter has a relatively large number of parts, and accordingly requires a cumbersome or complex fabrication process.

On the other hand, a three-layered or so-called tri-plate type dielectric filter as disclosed in laid-open Publication No. 59-51606 of unexamined Japanese Patent Application, for example, is free from such drawbacks. Namely, it is recognized in the art that the tri-plate type dielectric filter can be comparatively easily fabricated, with a considerably reduced thickness. An example of the dielectric filter of the tri-plate construction is illustrated in Figs. 12 and 13. This dielectric filter, which is indicated generally at 2 in Fig. 12, has a dielectric substrate 6 in which there is embedded a patterned array of an input and an output electrode 3 and a plurality of stripline resonator electrodes 4 (three electrodes 4 in this specific example). The outer surfaces of the dielectric substrate 6 are coated with a ground conductor 8 (respective conductive films 8), except certain areas on a pair of opposed side surfaces, on which an input and an output contact 10 are formed, respectively. Thus, the dielectric filter 2 is fabricated to be considerably compact and thin.

In the known tri-plate type dielectric filter 2 shown in Fig. 13, the resonator electrodes 4 are formed so as to provide a comb-shaped or interdigital structure, and the desired filtering properties are obtained by adjusting the spacing between the adjacent resonator electrodes 4. That is, the dielectric filter 2 does not have a circuit for electrically connecting the resonator electrodes 4. However, the applicants recognized a need for providing such an electrically connecting circuit so as to provide capacitors between the adjacent electrodes 4, in order to meet recent stringent requirements for improved properties of the dielectric filter for the microwave frequencies, which cannot be dealt with by the mere provision of a simple comb-shaped or interdigital structure of the resonator electrodes.

Conventionally, the final fine adjustment to obtain the desired frequency characteristic of the dielectric filter 2 is accomplished by trimming a portion of the ground conductor 8 which corresponds to the resonator electrodes 4, or by trimming the short-circuited ends of the electrodes 4 that are electrically connected to the conductor 8. However, the positions of the electrodes 4 embedded in the dielectric substrate 6 cannot be accurately detected, and the trimming is difficult to achieve the desired frequency characteristic of the filter.

SUMMARY OF THE INVENTION

The present invention was developed to solve the problem encountered in the prior art as described above. It is therefore a first object of this invention to provide a tri-plate type dielectric filter which exhibits improved filtering properties, without an increase in the size and the number of parts, as defined in claim 1.

A filter with the features of the preamble of claim 1 is known from patent document EP-A-0 414 619. Further advantageous embodiments are defined in claims 2 to 8.

A second object of the invention is to provide a method suitable for facilitating adjustment of the frequency characteristic of such dielectric filter, as defined in claim 9.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and optional objects, features and advantages of the present invention will be better understood by reading the following detailed description of presently preferred embodiments of the invention, when considered in connection with the accompanying drawings, in which:

Fig. 1 is a perspective view showing one embodiment of a dielectric filter of the present invention;
Fig. 2 is a cross sectional view taken along line 2-2 of Fig. 1;
Fig. 3 is a perspective view showing another embodiment of the dielectric filter of the invention;
Fig. 4 is a plan view of a first dielectric plate of the dielectric filter of Fig. 3;
Fig. 5 is a plan view of a second dielectric plate of the dielectric filter of Fig. 3;
Fig. 6 is a cross sectional view taken in a cutting plane indicated in dashed line in Figs. 4 and 5;
Fig. 7 is a view showing an equivalent circuit of the

dielectric filter of Fig. 3

Fig. 8 is a perspective view showing a further embodiment of the dielectric filter of this invention.

Fig. 9 is an exploded perspective view of the dielectric filter of Fig. 8.

Fig. 10 is a view showing an equivalent circuit of the dielectric filter of Fig. 8.

Fig. 11 is a graph indicating a relationship between the frequency and the damping effect of the filter of Figs. 8-10.

Fig. 12 is a perspective view showing a known dielectric filter; and

Fig. 13 is a cross sectional view taken along line 13-13 of Fig. 12.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to Figs. 1 and 2, there is shown one example of a three-layered or tri-plate type dielectric filter constructed according to the principle of the present invention. The dielectric filter, as indicated generally at 12 in Fig. 1, is a generally rectangular structure whose six surfaces include two opposite major surfaces and four side surfaces. All of these six surfaces are coated with a ground conductor 14, namely, with respective six conductive films 14. However, small areas on the opposite two longer side surfaces are left uncovered with the conductive films 14, so that respective two input and output contacts 16, 16 are formed on those areas, as shown in Figs. 1 and 2, such that the contacts 16 are electrically insulated from the ground conductor 14 (conductive films). Within the mass of the dielectric filter 12, there are embedded a plurality of resonator electrodes 18, an input and an output electrode 20, and a plurality of coupling electrodes 22, 26, as described below.

The dielectric filter 12 is a laminar structure fabricated by a common laminating method. The laminar structure includes a dielectric substrate 24 as shown in Fig. 2. On one major surface of this dielectric substrate 24, there is formed a patterned array of three parallel equi-spaced elongate strips 18 as the resonator electrodes. Further, the input and an output electrode 20 are formed on the same surface, such that these input and output electrodes 20 are electrically connected to the input and output contacts 16. These two electrodes 20 are positioned on the opposite sides of the array of the elongate strips 18. The three elongate strips 18 are formed in a comb-shaped pattern, so as to provide the respective resonators. The strips 18 have short-circuited first ends which are electrically connected to each other by means of the conductive film 14 formed on one of the opposite shorter side surfaces of the dielectric substrate 24. The other or second ends of the elongate strips 18 are located at a suitable distance inward of the other shorter side surface of the substrate 24. It will be understood that the parallel elongate strips 18 extend along the longer side surfaces of the substrate 24, and are spaced apart from each other in the direction parallel to the shorter side surfaces of the substrate 24.

The coupling electrodes 22 are formed integrally with the second ends of the elongate strips 18, such that each electrode 22 extends toward the second ends of the adjacent strips 18. As shown in Fig. 2, the coupling electrodes 22 formed with the strips 18 are spaced apart from each other in the direction perpendicular to the direction of extension of the strips 18, for capacitively connecting the elongate strips 18 at their second ends. The thus patterned array of the coupling electrodes 22 provides capacitors between the second ends of the adjacent strips 18. The capacitance values of these capacitors can be adjusted by suitably patterning the array of the electrodes 22, whereby the desired filtering property of the filter 12 can be obtained. This adjustment is not possible on the known dielectric filter.

Between the patterned array of the coupling electrodes 22 and the shorter side surface of the substrate 24 opposite to the shorter side surface at which the first ends of the elongate strips 18 are connected to each other by the conductive strip 14, there is formed a generally U-shaped coupling electrode 26 for capacitively connecting the two outer elongate strips 18 at their second ends. Namely, two capacitors are provided, one between one end of the coupling electrode 26 and one of the two outer strips 18, and the other between the other end of the electrode 26 and the other outer strip 18. The capacitance values of these capacitors can also be adjusted by suitably patterning the coupling electrode 26, whereby the frequency characteristic of the dielectric filter can be improved.

The provision of the coupling electrodes 22, 26 makes it possible to meet stringent requirements for improved characteristic of the filter 12, while maintaining the filter 12 sufficiently thin and small-sized, with the electrodes 22, 26 as well as the elongate strips (resonator electrodes) 18 being embedded in the mass of the dielectric filter 12. Thus, the improved dielectric filter 12 can be obtained without increasing the size or the number of process steps. It is to be noted that the coupling electrode 26 for capacitively connecting the two outer elongate strips 18 is not essential according to the principle of this invention.

Referring next to Figs. 3-7, there will be described another example of the tri-plate type dielectric filter, which is indicated generally at 28 in Fig. 3. The dielectric filter 28 is coated with the ground conductor 14, except for one of the opposite shorter side surfaces, on which the second ends of the elongate strips 18 (resonator electrodes) are exposed, as shown in Fig. 3. As in the first embodiment of Figs. 1 and 2, the first ends of the strips 18 are short-circuited, i.e., electrically connected to each other by the conductive film 14 on the other of the opposite short side surfaces of the filter 28. Unlike the input and output contacts 16 in the first embodiment, the contacts 16 in the present embodiment are formed

on corner portions provided by the top surface and the opposite long side surfaces of the filter 28, which are adjacent to the opposite ends of the short side surface on which the second ends of the strips 18 are exposed. These input and output contacts 16 are electrically insulated from the conductive films 14 on the top and long side surfaces of the filter 28. Namely, the corner portions indicated above are left uncovered by the conductive films 14.

The dielectric filter 28 uses two dielectric substrates 30, 32 as shown in Figs. 4 and 5, respectively. The patterned array of equi-spaced parallel elongate strips 18 is formed on the first dielectric substrate 30, while the three coupling electrodes 22 for capacitively connecting the adjacent elongate strips 18 are formed on the second dielectric substrate 32. The first ends of the strips 18 are short-circuited on one of the opposite shorter side surfaces of the first substrate 30, while the second ends of the strips 18 are exposed on one of the opposite shorter side surfaces of the second substrate 32, which is opposite to the above-indicated one shorter side surface of the first substrate 30. The three coupling electrodes 22 are patterned such that these electrodes 22 are positioned right above and spaced apart from the second ends of the corresponding strips 18 when the first and second substrates 30, 32 are superposed on each other. A green laminar structure consisting of the superposed first and second substrates 30, 32 is fired into a blank for the dielectric filter 28.

The thus prepared blank for the dielectric filter 28 is trimmed at a suitable position as indicated in dashed lines in Figs. 4 and 5, which indicate a trimming plane which corresponds to the shorter side surface of the filter 28 on which the second ends of the strips 18 and the corresponding coupling electrodes 22 are exposed, as shown in Fig. 6.

Reference is now made to Fig. 7 showing an equivalent circuit of the dielectric filter 28. The equivalent circuit includes three resonators 34 corresponding to the three elongate strips 18, three capacitors 36 provided between the strips 18 and the coupling electrodes 22, and two capacitors 38 provided between the adjacent electrodes 22. The capacitance values of these capacitors 36, 38 can be adjusted as desired by suitably patterning the coupling electrodes 22, whereby the desired filtering property can be obtained, without increasing the size and complexity of the filter 28, with the coupling electrodes 22 embedded within the first and second dielectric substrate 30, 32.

In the present second embodiment, the coupling electrodes 22 are provided on the second dielectric substrate 32 and are spaced apart from the second ends of the elongate strips or resonator electrodes 18. Accordingly, the coupling electrodes 22 have a higher degree of freedom of patterning, without a design limitation by the second ends of the strips 18 as existing in the first embodiment. Thus, the present arrangement permits a relatively complicated circuit for capacitive connection of the second ends of the elongate strips 18 by the coupling electrodes 22.

In the second embodiment, the two outer coupling electrodes 22 serve also as the input and output electrodes (20), which are exclusively provided in the first embodiment. As shown in Fig. 7, these two outer coupling electrodes 22 provide respective capacitors 40 associated with the input and output contacts 16. The capacitance values of these input and output capacitors 40 can also be adjusted by suitably patterning the two outer coupling electrodes 22.

As described above, the dielectric filter 28 is trimmed at the second ends of the elongate strips 18 and the corresponding coupling electrodes 22, for fine adjustment of the frequency characteristic of the filter. The trimming operation for this adjustment is simple and easy, contributing to improved efficiency of fabrication of the filter 28.

Referring further to Figs. 8-11, there will be described a further example of the tri-plate type dielectric filter, which is indicated generally at 42 in Fig. 8. The dielectric filter 42 is coated with the ground conductor 14, except for some areas of one of the opposite short side surfaces, on which the second ends of the respective elongate strips 18 are exposed, as shown in Fig. 8. That is, parallel spaced-apart elongate conductive strips 14a are formed on the above-indicated one short side surface of the dielectric filter 42, such that these conductive strips 14a define areas on which the respective elongate strips 18 of the resonator electrodes are exposed.

As in the first and second embodiments of Figs. 1-7, the first ends of the strips 18 are short-circuited by the conductive film 14 on the other of the opposite short side surfaces of the filter 42. As in the first embodiment of Fig. 1-2, the contacts 16 in this embodiment are formed on the opposite long side surfaces of the filter 42, and are electrically insulated from the conductive films 14 on the long side surfaces of the filter 42.

More specifically, four substrates 44, 46, 48, 50 as shown in Fig. 9 are superposed on each other so as to form the dielectric filter 42 in which are embedded the coupling electrodes 22, elongate strips 18 and input and output electrodes 20. As shown in Fig. 9, the elongate strips 18 are formed on the third dielectric substrate 48 whose first ends are short-circuited by the conductive film 14 and whose seconds ends are exposed between the adjacent conductive strips 14a on one of the opposite short side surfaces of the filter 42, as described above. Further, the two coupling electrodes 22 for capacitively connecting the elongate strips 18 are formed on the second dielectric substrate 46 such that the coupling electrodes 22 are positioned right above and spaced apart from the second ends of the elongate strips 18. A green laminar structure consisting of the superposed four substrates 44, 46, 48, 50 is fired into a blank for the dielectric filter 42.

There is illustrated in Fig. 10 an equivalent circuit of

the dielectric filter 42 which includes three resonators 34 corresponding to the three elongate strips 18, and four capacitors 36 provided between the strips 18 and the coupling electrodes 22. The adjacent resonators 34 are electrically connected to each other through the capacitors 36 and the coupling electrodes 22. The capacitance values of the capacitors 36 can be adjusted as desired by suitably patterning the coupling electrodes 22 so as to obtain the desired filtering property.

Further, the elongate conductive strips 14a of the conductor 14 effectively eliminate a difference in potential between the conductive films 14 on the opposite top and bottom surfaces of the dielectric filter 42, thereby assuring improved stability of the filtering characteristics of the filter 42.

The equivalent circuit also includes three capacitors 52 between the exposed or second end portions of the elongate strips 18 and the elongate conductive strips 14a on the corresponding short side surface of the dielectric filter 42, as indicated in Fig. 10. In the presence of these capacitors 52, the elongate strips 18 serving as the resonator electrodes are made inductive with respect to the resonance frequency, whereby there are provided an inductor M between the adjacent resonators 34. Thus, each resonator 34 is provided with a capacitor 36 and an inductor M, and the effect of damping by the instant dielectric filter on the input microwave spectrum is smaller in a frequency band of the spectrum lower than the pass band, than the effect of damping by the known dielectric filter, as indicated in the graph of Fig. 11. This means improved capability of filtering the desired frequency band. In addition, the provision of the capacitors 52 makes it possible to reduce the length of the resonators 34, for the same resonance frequency, thereby contributing to reduction in the size of the dielectric filter 42.

According to the present invention, the resonator electrodes 18 in the form of the elongate strips and the coupling electrodes 22 which are entirely embedded within the dielectric substrate (24) or substrates (30, 32; 44, 46, 48, 50) are preferably formed of an electrically conductive material whose resistivity is relatively small, whose major component or components is/are Au, Ag and/or Cu, for example. Since the loss at the electrodes 18, 22 increases the loss of the filter in the pass band, it is desired that the resistivity of the connecting circuit be sufficiently low, particularly where the filter deals with the electromagnetic wavelengths in the microwave spectrum.

Where a Ag- or Cu-based electrically conductive material is used for the electrodes 18, 22, it is necessary to use a dielectric material (for the dielectric substrate or substrates 24, 30, 32) which can be fired or sintered at a temperature lower than the melting point (1100°C or lower) of such electrically conductive material, since the melting point of the Ag- or Cu-based conductive material is too low to permit co-firing of the conductive material with an ordinary dielectric material. Where the dielectric filter is used as a microwave filter, it is desirable that the dielectric material is selected to assure that the temperature coefficient of the resonance frequency of resonance circuits corresponding to the resonator electrodes 18 be held not higher than ±50ppm/°C. Examples of the preferred dielectric material include a glass composition consisting of a mixture of a cordierite glass powder, a TiO_2 powder and a $Nd_2Ti_2O_7$ powder, and a mixture consisting of a BaO-TiO_2-RE_2O_3-Bi_2O_3 composition (RE: rare earth component) and a small amount of a glass forming component or a glass powder.

To further clarify the present invention, there will be described some examples of the present invention. However, it is to be understood that the invention is not limited to the details of the following examples, but may be embodied with various changes, modifications and improvements, which may occur to those skilled in the art, without departing from the spirit of the invention.

Example 1

A powder mixture was prepared by sufficiently mixing 73 wt.% of a glass powder, 17wt.% of a TiO_2 powder and 10 wt.% of an $Nd_2Ti_2O_7$ powder. The glass powder consists of 18 wt.% of MgO, 37 wt.% of Al_2O_3, 37 wt.% of SiO_2, 5 wt.% of B_2O_3 and 3 wt.% of TiO_2. The $Nd_2Ti_2O_7$ powder was obtained by mixing Nd_2O_3 powder and TiO_2 powder, calcining the mixture at 1200°C, and milling the calcined powder mass. To the prepared powder mixture, there were added an acrylic-based organic binder, a plasticizer, toluene and alcohol solvents. The powder mixture and these additives were well mixed by alumina balls, whereby a slurry was obtained. Using the slurry, green tapes having a thickness of 0.2-0.5mm were formed by a doctor-blade method.

On the other hand, a Ag powder, an acrylic-based organic binder and a terpineol-based organic solvent were sufficiently kneaded by a three-roll method, whereby an electrically conductive printing paste was prepared. Using the printing paste, a pattern of electrically conductive material corresponding to the electrodes 18, 20, 22, 26 as shown in Fig. 2 was formed on some of the green tapes, while a conductive layer corresponding to the ground conductive films 14 was formed on one surface of the other green tapes. One green tape having the pattern of electrodes and two green tapes each having the conductive layer were superposed on each other so that the pattern of electrodes are interposed by the two green tapes having the conductive layers, such that the two conductive layers form the opposite surfaces of the obtained laminar green tape. The laminar green tape was compacted at 100°C under 100kg/cm². The compacted laminar green tape was cut into pieces each corresponding to the dielectric filter 12 of Fig. 1. Then, the printing paste was applied to the four side surfaces of each piece, to form conductive pads corresponding to the input and output contacts, and conductive layers corresponding to the conductive films 14 on the four side

surfaces of the filter 12. Thus, a plurality of precursors for the dielectric filter 12 were prepared. These precursors were fired in the atmosphere, for 30 minutes at 900°C, whereby thin microwave filters having a total thickness of 2mm were produced.

These filters had a band width of 20MHz and an insertion loss of 3dB, where the nominal frequency was 900MHz. A sintered test piece was prepared by using the powder mixture described above. The test piece was ground to predetermined dimensions, and its temperature coefficient of the resonance frequency in the microwave spectrum was measured according to Hakki & Coleman method, over a temperature range from -25°C to +75°C. The measured temperature coefficient was +10ppm/°C.

Example 2

A powder mixture was prepared by sufficiently mixing 73 wt.% of a glass powder, 17wt.% of a TiO_2 powder and 10 wt.% of an $Nd_2Ti_2O_7$ powder. The glass powder consists of 17 wt.% of MgO, 37 wt.% of Al_2O_3, 37 wt.% of SiO_2, 5 wt.% of B_2O_3, 3 wt.% of TiO_2 and 1 wt.% of MnO. The TiO_2 powder was obtained by mixing commercially available TiO_2 and MnO powders, calcining the mixture at 1200°C, and milling the calcined powder mass. The $Nd_2Ti_2O_7$ powder was obtained by Nd_2O_3 powder, TiO_2 powder and MnO powder, calcining the mixture at 1200°C, and milling the calcined powder mass.

To the prepared powder mixture, there were added an acrylic-based organic binder , a plasticizer, toluene and alcohol solvents. The powder mixture and these additives were mixed by alumina balls, whereby a slurry was obtained. Using the slurry, green tapes having a thickness of 0.2-0.5mm were formed by a doctor-blade method.

On the other hand, a Cu powder, an acrylic-based organic binder and a terpineol-based organic solvent were sufficiently kneaded by a three-roll method, whereby an electrically conductive printing paste was prepared. Using the printing paste, a pattern of electrodes and a conductive layer were printed on the green tapes, and compacted laminar green tapes for the filter 12 of Fig. 1 were prepared, as in Example 1. Then, precursors for the dielectric filter 12 were prepared by applying the printing paste to the laminar green tapes, as in Example 1. The precursors were fired in a nitrogen atmosphere, for 30 minutes at 950°C, whereby thin microwave filters having a total thickness of 2mm were produced. These filters had a band width of 30MHz and an insertion loss of 3.5dB, where the nominal frequency was 900MHz.

Example 3

A pattern of electrically conductive material corresponding to the resonator electrodes 18, 20, 22, 26 was printed on the green tapes as prepared in Example 1, by using a Ag paste, and compacted laminar green tapes for the filter 12 were prepared. Then, a commercially available Cu paste was applied to form conductive films and pads corresponding to the ground conductive films 14 and input and output contacts 16, whereby precursors for the filter 12 of Fig. 1 were obtained. The precursors were fired in the atmosphere, for 30 minutes at 600°C, into 2-mm thick microwave filters. These filters had a band width of 20 MHz and an insertion loss of 3dB, where the nominal frequency was 900MHz.

Example 4

A powder mixture was prepared by adding a total of 8 wt.% of a low-melting point glass powder and a low-melting point metal oxide powder, to 92 wt.% of a powdered $BaO-TiO_2-Nd_2O_3-Bi_2O_3$ composition. To the prepared powder mixture, there were added an acrylic-based organic binder , a plasticizer, toluene and alcohol solvents. The powder mixture and these additives were well mixed by alumina balls, whereby a slurry was obtained. Using the slurry, green tapes having a thickness of 0.2-0.5mm were formed by a doctor-blade method.

On the other hand, a Ag powder, an acrylic-based organic binder and a terpineol-based organic solvent were sufficiently kneaded by a three-roll method, whereby an electrically conductive printing paste was prepared. Using the printing paste, a pattern of electrically conductive material corresponding to the resonator electrodes 18 as shown in Fig. 4 was formed on some of the green tapes, while a pattern of electrically conductive material corresponding to the coupling electrodes 22 were formed on the other green tapes. Further, a conductive layer corresponding to the ground conductive film 14 and conductive pads corresponding to the input and output contacts 16 as shown in Fig. 3 were formed on one surface of the yet other green tapes. The following four green tapes were superposed on each other in the order of description: one green tape having the conductive layer and the two conductive pads; two green tapes one having the pattern for the resonant electrodes 18 and the other having the pattern for the coupling electrodes 22; and one green tape having the conductive layer. The prepared laminar green tape was compacted at 100°C under 100kg/cm^2. The compacted laminar green tape was cut into pieces each corresponding to the dielectric filter 28 of Fig. 3. Then, the printing paste was applied to the four side surfaces of each piece, to form conductive layers corresponding to the conductive films 14 on the four side surfaces of the filter 28. Thus, a plurality of precursors for the dielectric filter 28 were prepared. These precursors were fired in the atmosphere, for 30 minutes at 900°C, whereby thin microwave filters having a total thickness of 2mm were produced.

These filters 28 had a band width of 20MHz and an insertion loss of 3dB, where the nominal frequency was 900MHz. A sintered test piece was prepared by using

the powder mixture used for producing the filters 28. The test piece was ground to predetermined dimensions and its temperature coefficient of the resonance frequency in the microwave spectrum was measured according to Hakki & Coleman method, over a temperature range from -25°C to +75°C. The measured temperature coefficient was +15ppm/°C. Before the measurement, a fine adjustment of the frequency characteristic of the test piece was made by trimming the second ends of the resonator electrodes 18 and the coupling electrodes 22.

Example 5

A powder mixture was prepared by adding a total of 8 wt.% of a low-melting point glass powder and a low-melting point metal oxide powder, to 92 wt.% of a powdered BaO-TiO_2-Nd_2O_3-Bi_2O_3 composition. To the prepared powder mixture, there were added an acrylic-based organic binder, a plasticizer, toluene and alcohol solvents. The powder mixture and these additives were well mixed by alumina balls, whereby a slurry was obtained. Using the slurry, green tapes having a thickness of 0.2-0.5mm were formed by a doctor-blade method.

On the other hand, a Ag powder, an acrylic-based organic binder and a terpineol-based organic solvent were sufficiently kneaded by a three-roll method, whereby an electrically conductive printing paste was prepared. Using the printing paste, patterns of electrically conductive material corresponding to the resonator electrodes 18, input and output electrodes 20 and coupling electrodes 22 as shown in Fig. 9 were formed on respective green tapes for the third, fourth and second dielectric substrates 48, 50 and 46. Further, conductive films corresponding to the top and bottom conductor films 14 were formed on the appropriate green tapes. The green tapes having the conductive patterns and films were superposed on each other in the appropriate order. The thus prepared laminar green tape was compacted at 100°C under 100kg/cm^2. The compacted laminar green tape was cut into pieces each corresponding to the dielectric filter 42 of Fig. 8. Then, the printing paste was applied to the four side surfaces of each piece, to form conductive layers corresponding to the conductive films 14 and strips 14a on the four side surfaces of the filter 42. Thus, a plurality of precursors for the dielectric filter 42 were prepared. These precursors were fired in the atmosphere, for 30 minutes at 900°C, whereby thin microwave filters having a total thickness of 2mm were produced.

These filters 42 had a band width of 20MHz and an insertion loss of 3dB, where the nominal frequency was 900MHz. A sintered test piece was prepared by using the powder mixture used for producing the filters 42. The test piece was ground to predetermined dimensions and its temperature coefficient of the resonance frequency in the microwave spectrum was measured according to Hakki & Coleman method, over a temperature range from -25°C to +75°C. The measured temperature coefficient was +15ppm/°C. Before the measurement, a fine adjustment of the frequency characteristic of the test piece was made by trimming the second ends of the resonator electrodes 18 and the coupling electrodes 22.

Claims

1. A tri-plate type dielectric filter having a dielectric substrate (24, 30, 32, 44, 46, 48, 50) and a plurality of resonator electrodes (18) embedded in said substrate, characterized in that coupling electrodes (22, 26) are formed within said dielectric substrate spaced from said resonator electrodes, for capacitively coupling said plurality of resonator electrodes, so as to provide capacitors (36, 38) each between adjacent ones of said resonator electrodes.

2. A tri-plate type dielectric filter according to claim 1, wherein a ground conductor (14, 14a) is provided on a first outer surface of said dielectric substrate (24, 30, 32, 44, 46, 48, 50), and said plurality of resonator electrodes (18) have short-circuited first ends connected to each other by said ground conductor.

3. A tri-plate type dielectric filter according to claim 2, wherein said plurality of resonator electrodes (18) consist of a plurality of elongate strips, respectively, said elongate strips being formed substantially in parallel with each other.

4. A tri-plate type dielectric filter according to claim 2 or claim 3, wherein each of said resonator electrodes (18) has a second end opposite to said short-circuit first end thereof, further coupling electrodes (22) being formed integrally with said second ends of said resonator electrodes.

5. A tri-plate type dielectric filter according to any one of the preceding claims, wherein said coupling electrodes (22, 26) include a coupling electrode (26) for capacitively coupling the two outermost electrodes of said resonator electrodes (18).

6. A tri-plate type dielectric filter according to any one of claims 2 to 5, wherein each of said resonator electrodes (18) provides a stripline type $\lambda/4$ or $\lambda/2$ TEM mode resonance circuit, and has a second end which is exposed on a second outer surface of said dielectric substrate (30, 32, 44, 46, 48, 50).

7. A tri-plate type dielectric filter according to claim 6, wherein said coupling electrodes (22) correspond to said resonator electrodes (18), respectively, said exposed second end of each said resonator electrodes (18) being spaced from a corresponding one of said coupling electrodes (22), in a direction of thickness of said dielectric substrate (30, 32,

44 46 48 50).

8. A tri-plate type dielectric filter according to claim 6 or claim 7, wherein said ground conductor (14, 14a) includes a top and a bottom conductive films (14) formed on opposite top and bottom surfaces as said first outer surface of said dielectric substrate (44 46 48 50), respectively, and a plurality of conductive strips (14a) formed on a side surface as said second outer surface of said dielectric substrate, so as to electrically connect said top and bottom conductive films (14), such that said second ends of said resonator electrodes (18) are electrically insulated from said conductive strips (14a).

9. A method of adjusting a frequency characteristic of a tri-plate type dielectric filter as defined in any one of claims 6 to 8, characterized by comprising the step of trimming said second end of each said resonator electrodes (18), to thereby adjust a resonance frequency of the corresponding resonance circuit.

Patentansprüche

1. Dielektrisches Filter vom Dreiplatten-Typ mit einem dielektrischen Substrat (24;30, 32; 44, 46, 48, 50) und einer Vielzahl von im Substrat eingebetteten Resonatorelektroden (18), dadurch gekennzeichnet, daß Kopplungselektroden (22, 26) innerhalb des dielektrischen Substrats im Abstand von den Resonatorelektroden ausgebildet sind, um die Vielzahl von Resonatorelektroden kapazitiv zu koppeln, um Kondensatoren bzw. Kapazitäten (36, 38) jeweils zwischen benachbarten Resonatorelektroden bereitzustellen bzw. vorzusehen.

2. Dielektrisches Filter vom Dreiplatten-Typ nach Anspruch 1, worin ein Masseleiter (14, 14a) an einer ersten Außenfläche des dielektrischen Substrats (24; 30, 32; 44, 46, 48, 50) vorgesehen ist und die Vielzahl von Resonatorelektroden (18) kurzgeschlossene erste Enden aufweist, die durch den Masseleiter miteinander verbunden sind.

3. Dielektrisches Filter vom Dreiplatten-Typ nach Anspruch 2, worin die Vielzahl von Resonatorelektroden (18) aus einer Vielzahl jeweiliger länglicher Streifen besteht, wobei die länglichen Streifen im wesentlichen parallel zueinander ausgebildet sind.

4. Dielektrisches Filter vom Dreiplatten-Typ nach Anspruch 2 oder 3, worin jede der Resonatorelektroden (18) ein zweites Ende gegenüber seinem kurzgeschlossenen ersten Ende aufweist, wobei weiters Kopplungselektroden (22) einstückig mit den zweiten Enden der Resonatorelektroden ausgebildet sind.

5. Dielektrisches Filter vom Dreiplatten-Typ nach einem der vorangegangenen Ansprüche, worin die Kopplungselektroden (22, 26) eine Kopplungselektrode (26) zum kapazitiven Koppeln der beiden äußersten Elektroden der Resonatorelektroden (18) umfassen.

6. Dielektrisches Filter vom Dreiplatten-Typ nach einem der Ansprüche 2 bis 5, worin jede der Resonatorelektroden (18) eine Streifenleitungsresonanzschaltung vom λ/4- oder λ/2 TEM-Mode bereitstellt und ein zweites Ende aufweist, das auf einer zweiten Außenfläche des dielektrischen Substrats (30, 32, 44, 46, 48, 50) freiliegt.

7. Dielektrisches Filter vom Dreiplatten-Typ nach Anspruch 6, worin die Kopplungselektroden (22) den Resonatorelektroden (18) jeweils entsprechend und das freiliegende zweite Ende einer jeden der Resonatorelektroden (18) von einer entsprechenden der Kopplungselektroden (22) in einer Dickenrichtung des dielektrischen Substrats (30, 32; 44, 46, 48, 50) beabstandet ist.

8. Dielektrisches Filter vom Dreiplatten-Typ nach Anspruch 6 oder 7, worin der Masseleiter (14, 14a) einen obersten und einen untersten leitenden Film (14) umfaßt, die auf gegenüberliegenden Deck- bzw. Bodenflächen als der ersten Außenfläche des dielektrischen Substrats (44, 46, 48, 50) ausgebildet sind, sowie eine Vielzahl leitender Streifen (14a), die auf einer Seitenfläche als der zweiten Außenfläche des dielektrischen Substrats ausgebildet sind, um den obersten und untersten leitenden Film (14) elektrisch zu verbinden, sodaß die zweiten Enden der Resonatorelektroden (18) elektrisch von den leitenden Streifen (14a) isoliert sind.

9. Verfahren zum Einstellen einer Frequenzcharakteristik eines dielektrischen Filters vom Dreiplatten-Typ, wie nach einem der Ansprüche 6 bis 8 definiert, dadurch gekennzeichnet, daß es den Schritt des Trimmens des zweiten Endes einer jeden Resonatorelektrode (18) umfaßt, um dadurch eine Resonanzfrequenz der entsprechenden Resonanzschaltung bzw. des entsprechenden Resonanzkreises einzustellen.

Revendications

1. Filtre diélectrique du type à trois plaques ayant un substrat diélectrique (24;30,32;44,46,48,50) et un certain nombre d'électrodes de résonateur (18) enfouies dans ledit substrat, caractérisé en ce que des électrodes de couplage (22,26) sont formées

dans ledit substrat diélectrique espacées desdites électrodes de résonateur pour coupler capacitivement ladite pluralité d'électrodes de résonateur afin de réaliser les condensateurs (36,38), chacun entre les électrodes adjacentes des électrodes de résonateur

2. Filtre diélectrique du type à trois plaques selon la revendication 1, dans lequel un conducteur de masse (14, 14a) est prévu sur une première surface externe du substrat diélectrique précité (24,50,52, 44,56,48,50) et la pluralité précitée d'électrodes de résonateur (18) ont des premières extrémités court-circuitées reliées les unes aux autres par le conducteur de masse

3. Filtre diélectrique du type à trois plaques selon la revendication 2, dans lequel la pluralité précitée d'électrodes de résonateur (18) consistent en un certain nombre de bandes allongées, respectivement, lesdites bandes allongées étant formées sensiblement parallèles les unes aux autres.

4. Filtre diélectrique du type à trois plaques selon la revendication 2 ou la revendication 3, dans lequel chacune des électrodes de résonateur précitées (18) a une seconde extrémité opposée à la première extrémité court-circuitée précitée de celles-ci, des électrodes de couplage (22) étant de plus formées intégralement avec lesdites secondes extrémités desdites électrodes de résonateur.

5. Filtre diélectrique du type à trois plaques selon l'une quelconque des revendications précédentes, dans lequel les électrodes de couplage précitées (22,26) comprennent une électrode de couplage (26) pour coupler capacitivement les deux électrodes les plus externes des électrodes de résonateur précitées (18).

6. Filtre diélectrique du type à trois plaques selon l'une quelconque des revendications 2 à 5, dans lequel chacune des électrodes de résonateur précitées (18) réalise un circuit de résonance en mode TEM $\lambda/4$ ou $\lambda/2$ du type à ligne de bande, et a une seconde extrémité qui est exposée sur une seconde surface externe du substrat diélectrique précité (30,32;44,46, 48,50).

7. Filtre diélectrique du type à trois plaques selon la revendication 6, dans lequel les électrodes de couplage précitées (22) correspondent respectivement aux électrodes de résonateur précitées (18), la seconde extrémité exposée précitée de chacune desdites électrodes de résonateur (18) étant espacée de l'une correspondante desdites électrodes de couplage (22), dans une direction d'épaisseur dudit substrat diélectrique (30,32,44,46,48,50)

8. Filtre diélectrique du type à trois plaques selon la revendication 6 ou la revendication 7, dans lequel le conducteur de masse précité (14,14a) comprend un film conducteur supérieur et un film conducteur inférieur (14) formés sur des surfaces supérieure et inférieure opposées comme première surface externe précitée du substrat diélectrique précité (44,46,48,50), respectivement, et un certain nombre de bandes conductrices (14a) formées sur une surface latérale comme la seconde surface externe précitée dudit substrat diélectrique, afin de relier électriquement lesdits films conducteurs supérieur et inférieur (14), de sorte que les secondes extrémités précitées des électrodes de résonateur précitées (18) sont isolées électriquement desdites bandes conductrices (14a)

9. Procédé de réglage d'une caractéristique de fréquence d'un filtre diélectrique du type à trois plaques comme défini dans l'une quelconque des revendications 6 à 8, caractérisé en ce qu'il comprend l'étape d'ajuster la seconde extrémité précitée de chacune des électrodes de résonateur précitées (18), pour régler de la sorte une fréquence de résonance du circuit de résonance correspondant.

FIG. 1

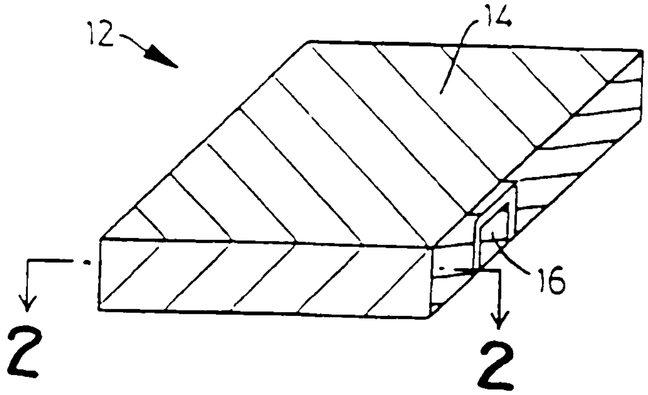
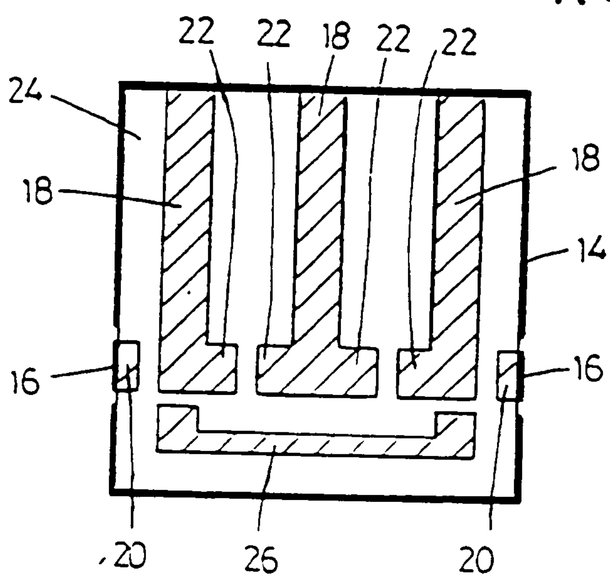


FIG. 2



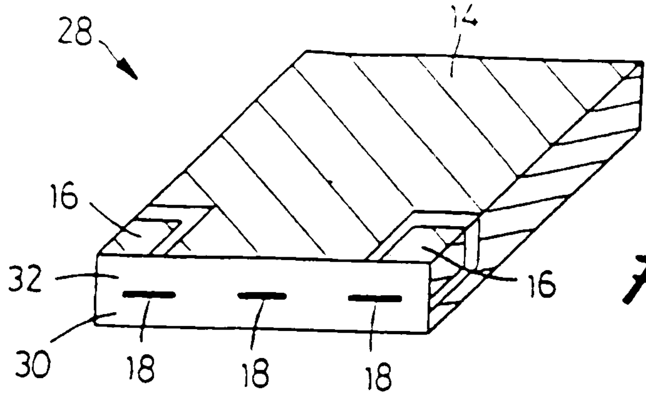


FIG. 3

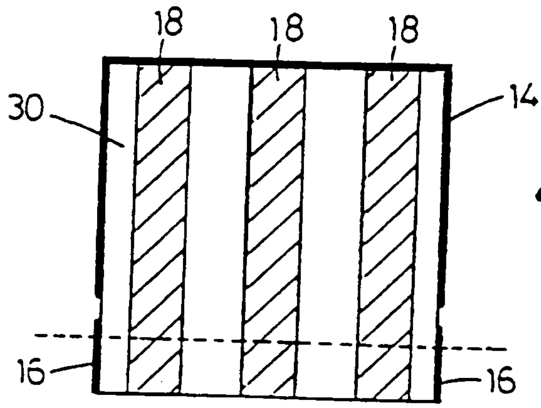


FIG. 4

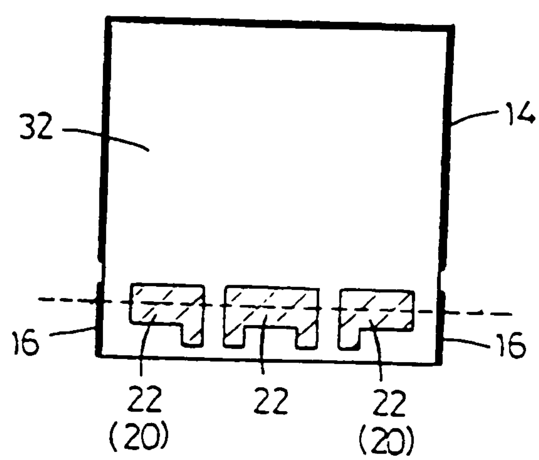


FIG. 5

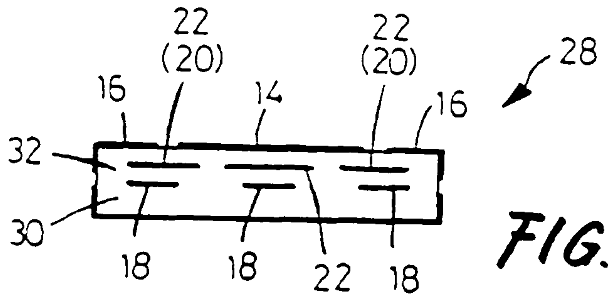

22
(20)
22
(20)
28
16
14
16
32
30
18
18
22
18

FIG. 6

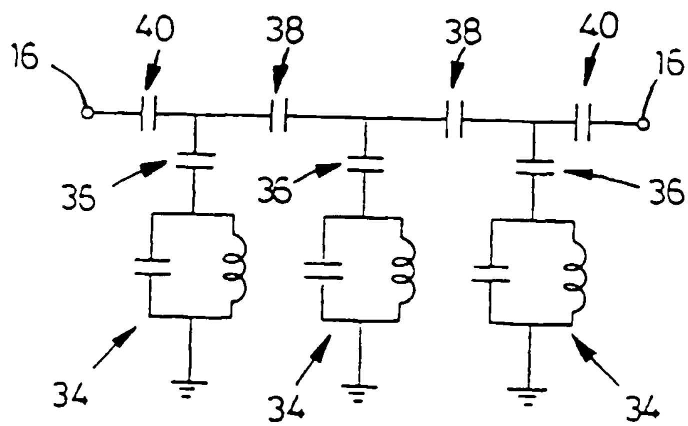

40
38
38
40
16
16
35
36
36
34
34
34

FIG. 7

FIG. 8

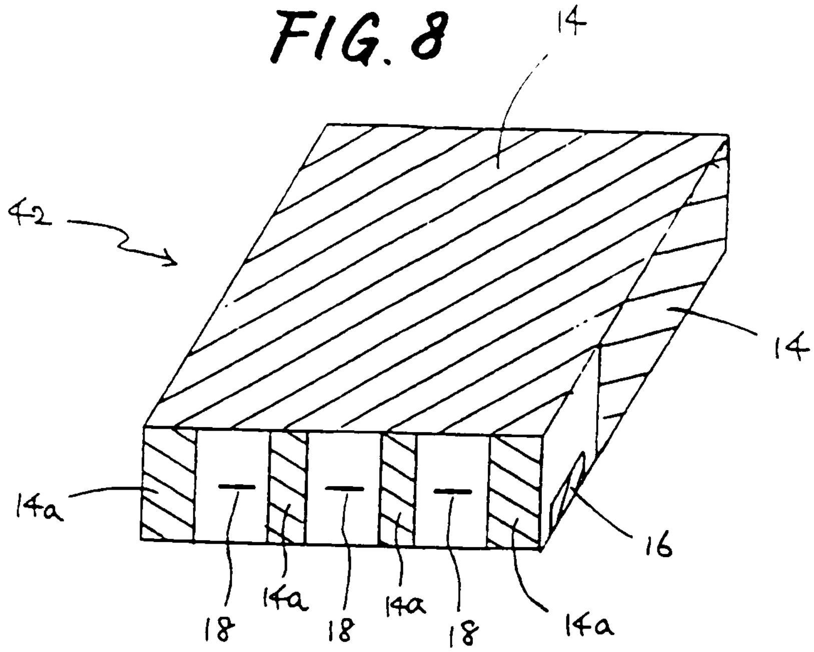

14
42
14
14a
16
18
14a
18
14a
18
14a

FIG. 10

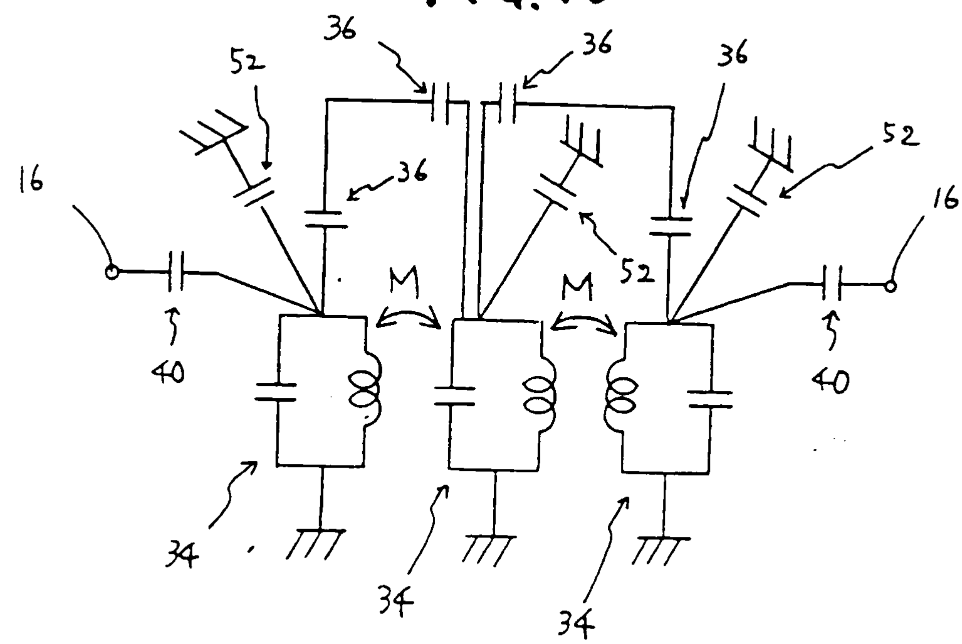

36
36
52
36
52
36
16
36
16
52
M
M
40
40
34
34
34

FIG. 9

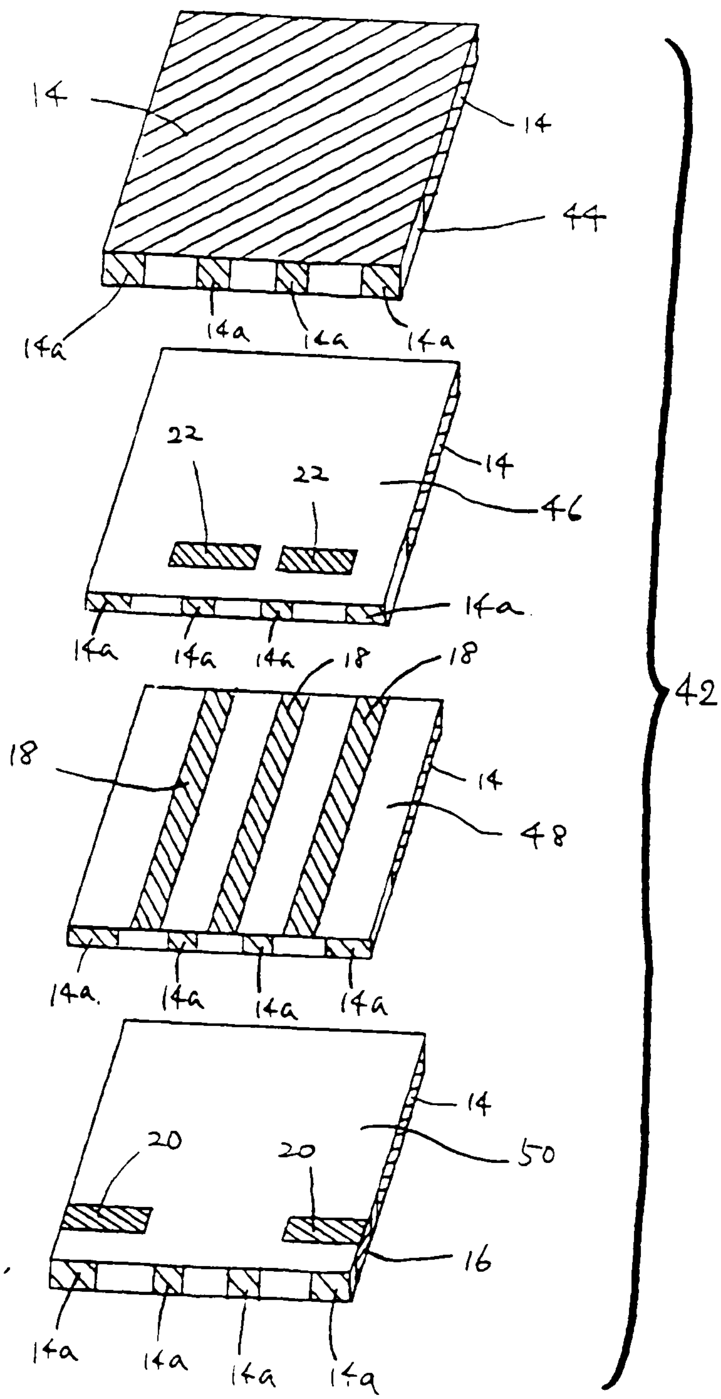
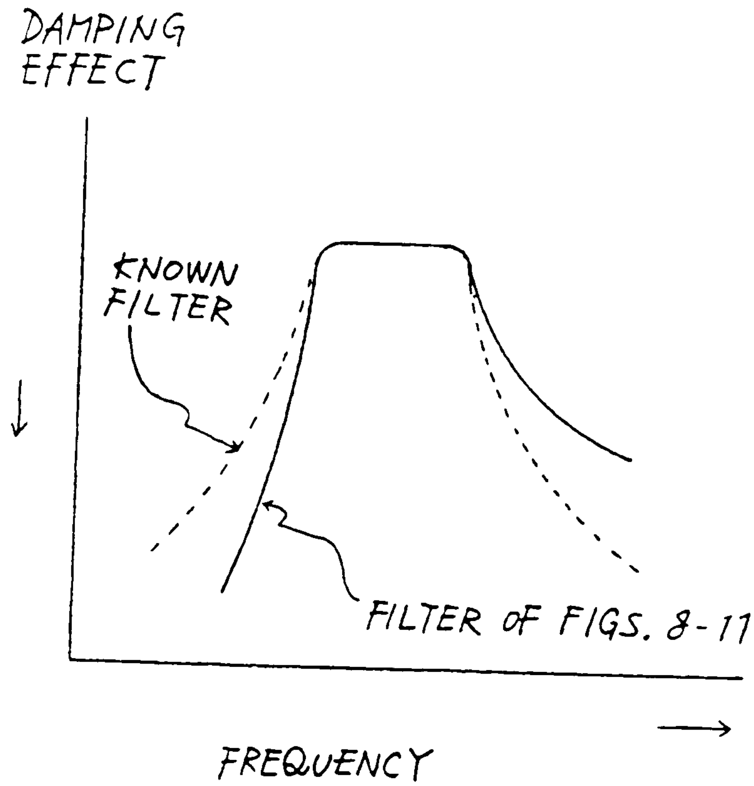
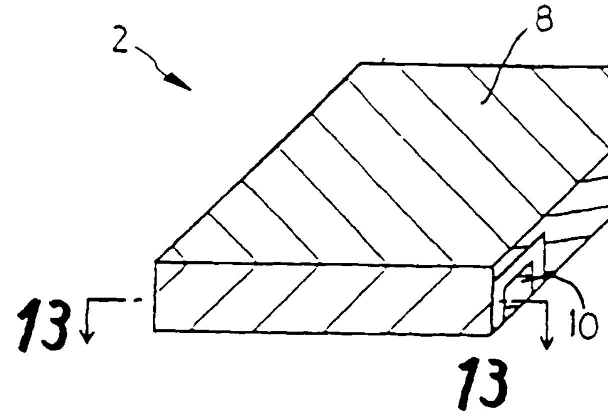

14
14
44
14a
14a
14a
14a
22
22
14
46
14a
14a
14a
14a
18
18
18
14
48
14a
14a
14a
14a
14
20
20
50
16
14a
14a
14a
14a
42

FIG. 11





PRIOR ART
FIG. 12

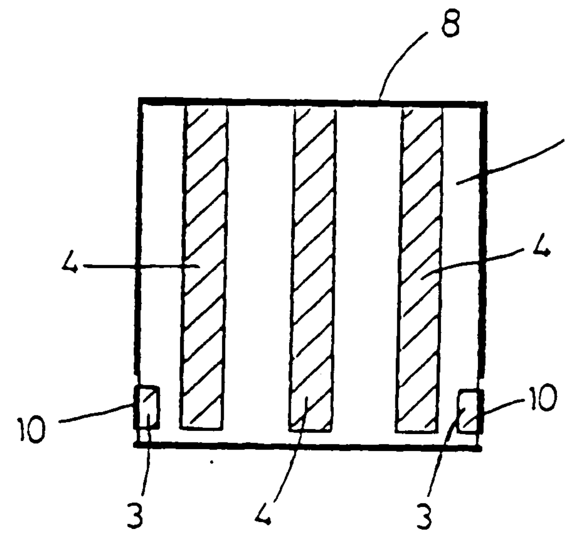


FIG. 13 PRIOR ART